An Economic Perspective on Tropical Deforestation

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I. Introduction

Tropical deforestation is not only a major environmental problem throughout the Third World, it is a critical development problem as well. Tropical forests have declined by nearly half in this century, and in most countries of Africa, Asia, and Latin America, the net rate of forest loss is rising (1). The underlying causes of deforestation are complex, involving economic, social, political, and institutional factors that affect forest resource use. Although these factors vary in importance from one region to another, the result is the same. Potentially renewable forest resources are being treated as nonrenewable resources due to harvesting rates that exceed regeneration and planting rates. Forest resource stocks are being depleted, and the environmental benefits of forests diminished or lost.

Deforestation is a growing threat to Third World development because it affects many areas of economic activity and human welfare. Tropical forests are closely linked to many subsistence and commercial activities through the raw materials they provide and the environmental services they perform. Because of these physical linkages, the forest-depleting activities of individual resource users can have widespread impacts. As deforestation progresses, agricultural productivity declines, energy supplies are disrupted, even human health is impaired. This is adversely affecting the daily lives of nearly two-thirds of the world's population and imposing significant costs on developing country economies.

This paper focusses on the economic dimensions of tropical deforestation, and the need for new analytical approaches to help guide efforts to solve it. Clearly, economics is but one of several important perspectives on the problem. Social, political, and institutional factors, both within and outside the forestry sector, that contribute to deforestation must also be addressed if lasting solutions are to be found (2).

II. Underlying Economic Forces

A fundamental economic problem underlies the activities contributing to deforestation—the private costs of forest exploitation do not reflect the costs incurred by society as forests are depleted. This divergence between private and social returns stems from the inability of markets—due to market failure or distortion of market incentives—to provide proper signals to individuals that would lead to an "optimum" level of forest resource use.

There are three major sources of this divergence. First, forest exploitation can have potentially large and widespread physical impacts, such as increased downstream erosion and sedimentation from loss of upland forests. These impacts, or "externalities," impose costs that individual resource users do not adequately account for. Because society bears the costs of these external impacts, they have no effect on individual behavior. Second, in most developing countries there is open access to common property forest lands. In the absence of property rights under open access, individuals have no incen-

tive to regulate their use of forests or to internalize the costs from externalities. Third, many countries have policies that distort market incentives and actually promote forest depletion. Because of externalities, open access, and inappropriate policy incentives, the economic (social) costs of forest depletion are significantly understated or ignored.

Physical Linkages and Externalities.

There are many physical linkages between tropical forests and human activities. Forests provide resources that are critical to meeting the daily needs of the rural and urban poor, and are an important source of raw materials for small and large-scale industrial uses. By protecting soil and water resources, forests help sustain the capacity of the environment to support agriculture and other sectors. Deforestation disrupts these physical linkages and externalities arise. The problems are familiar, such as fuelwood scarcity and soil erosion. What is less recognized, but of great importance, is the integrative nature of these problems. Impacts in one sector can have effects in another. The following is an overview of the direct and indirect impacts of deforestation (3).

1. *Agricultural impacts.*

Deforestation seriously impacts agricultural production through its effects on soil and water resources, fuelwood supplies, and the availability of tree fodder. These impacts differ in importance from one region to another.

Loss of environmental stability. The loss of forest cover on upland watersheds and semi-arid and humid lowlands reduces environmental stability and leads to degradation of the soil and water base for food production. An estimated 160 million hectares of upland watersheds have been seriously degraded throughout the developing world. The loss of upland forest cover has both on-site and downstream impacts. On-site soil erosion increases, reducing the productivity of the land. Downstream agriculture is threatened by effects on the water regime. Without the protection of forest cover, the regulation of stormflows is reduced or lost. The interception and storage of water by the roots and soil humus layers, and its release as a sustained flow of water to streams, is replaced by increased peak flows and surface water runoff. This, in turn, leads to increased soil erosion and sedimentation of rivers, which can intensify flooding in the lower reaches of rivers and result in widespread damage to lowland agricultural areas. The increased downstream transport of silt and debris from degraded uplands does considerable damage to critical storage reservoirs and irrigation developments, disrupting their operation and reducing their useful lifetime. In addition, disruption of the temporary storage and regulated flow of water leads to reduced dry season river flows available for irrigation. This has significant impacts on areas dependent on irrigated agriculture and is a constraint to the further spread of irrigation.

Large areas of the humid tropics have forest soils that are not capable of supporting continuous cultivation because of low fertility and poor structure. These areas would be properly considered marginal lands. The principal method of agriculture is shifting cultivation, in which forest areas are cleared and the vegetation burned to release nutrients to the soil. These areas are cultivated for two or three years, or until the accessible nutrients in the soil are

used up and crop yields begin to decline, and then are left to recover. As trees regenerate during the fallow period, they play a vital role in restoring nutrient cycles by drawing nutrients to the surface with their deep roots.

Forest loss, population growth, and other pressures have forced farmers to lengthen cropping periods and shorten fallows in shifting cultivation systems, allowing insufficient time for forest recovery. This breach in the natural cycle of regeneration leads to land degradation and a sharp reduction in crop yields.

In semi-arid and arid lowlands, deforestation is having severe impacts on agriculture. Because of the fragility of the soil and low and erratic rainfall, these areas have lower carrying capacities for people and their livestock and are particularly sensitive to human abuse. Wind is the primary agent of erosion. With the loss of tree cover, wind erosion increases and the moderating effects of trees on dust storms and sand dune formation are lost. This leads to a decrease in soil moisture and greater crop damage. The loss of trees also reduces the effectiveness of rainfall by decreasing the amount of water that percolates into the ground. Water runoff increases, erosion accelerates, the water table is lowered, and springs and wells dry up. Together with overgrazing and continuous cropping of marginal land, this exacerbates the effects on food production of periods of low rainfall or drought.

In its most extreme form, deforestation leads to desertification—a process of decline in the biological productivity of semi-arid and arid lands. Desertification is undermining the food-producing capacity of drylands throughout Africa, Asia, and Latin America. An estimated 1.3 billion hectares are at least moderately desertified in these three regions, and more than 300 million people live in areas at least moderately or severely desertified.

Fuelwood scarcity. Increasing scarcity of fuelwood supplies in upland hill areas and semi-arid lowlands significantly affects food production in two ways. First, as fuelwood becomes scarce the only readily available alternative for many families is to burn crop residues and animal dung. In small-holder farming systems, crop residues and dung are normally applied to crop fields to help maintain the productivity of the soil. Their use as fuel robs the soil of badly needed organic matter and nutrients and leads to poor soil structure, lower retention of available nutrients in the crop root zone, and reduced protection from the erosive effect of heavy rainfall. The failure to maintain soil productivity leads inevitably to declining crop yields. A second impact of scarcity is the increasing time that must be devoted to collecting fuelwood. Gathering and transporting fuelwood increasingly dominates the daily lives of millions of people in rural areas, particularly women and children. This shortens the time available for weeding and tending crops.

Loss of tree fodder. Deforestation negatively affects agricultural productivity through the loss of forest fodder supplies. Tree fodder plays an important role in many farming systems. It can be a valuable source of mulch for maintaining the productivity of croplands. In many upland areas forest fodder is also an essential source of feed for draft animals. As supplies dwindle, draft animal power is reduced. In semi-arid regions, tree fodder can account for a significant portion of the livestock feed requirements of migrant populations. Deforestation has resulted in

shortages of animal feed and forced migration away from degraded areas.

2. *Energy impacts.*

Deforestation is affecting the energy supplies of both rural and urban populations, subsistence and commercial users.

Wood energy. An estimated 1.5 billion people, or 70% of the 2 billion people who rely on wood to meet a major part of their household energy needs, are cutting wood faster than it is growing back. Some 125 million people cannot find enough wood to meet their needs, even by overcutting the forests. Thirty-four of the countries with fuelwood shortages have no proven oil or gas reserves, which, combined with low GNP per capita and low rates of economic growth, severely constrains their ability to switch from traditional biomass fuels to fossil fuels.

In urban areas, most households must buy fuelwood or charcoal. Prices have risen sharply in recent years as the circle of deforestation around cities and towns widens and fuelwood and charcoal must be transported over greater distances. In many areas, between 20 and 40 percent of the cash income of the average urban household must be set aside to buy wood or charcoal.

Hydroelectric supply. Hydropower plays a significant role in the electricity generation systems of many developing countries, and is particularly important in helping to reduce demand for imported oil or coal. Dams and generating facilities are major capital investments. In Asia, planned investments in hydropower development over the next decade total nearly $42 billion. As noted above, the loss of forest cover on upland watersheds disrupts the water regime and leads to increased flooding, soil erosion, and sedimentation of rivers. This is damaging reservoirs and accelerating the rate at which they are filling up with silt. The economic lifetime of many dams is being sharply reduced, and the supply of badly needed hydropower is being disrupted.

3. *Industrial forestry impacts.*

Industrial wood products such as sawnwood, plywood, and pulpwood are a source of essential building materials and of the paper needed for schoolbooks, newspapers, packing, and other uses. In addition, forests supply numerous so-called "minor" forest products that have a wide range of industrial applications. These include canes and fibers, essential oils, gums, resins, latexes, waxes, and tannins and dyes. Sustained development of the Third World implies a steady growth in demand for industrial forest products as literacy spreads and the needs for housing, paper, and other goods increases.

The depletion of commercial forest stocks in many developing countries is having serious economic consequences. Current levels of forest management and reforestation fall far short of what is needed to limit imports and sustain exports. Small-scale artisinal activities based on forest resources are affected as well.

Rising imports and declining exports. Deforestation is leading to a growing inability of many countries to meet their domestic needs for industrial forest products. Imports are increasing sharply, even in such countries as Nigeria, Thailand, and Mexico that should be readily able to supply their own needs. Nigeria, once a significant exporter of timber, now imports industrial forest products at a cost of more than $210 million annually. Overall, developing country imports rose from about $6 bil-

lion in the early 1970s to almost $10 billion in 1983.

Deforestation threatens developing country exports of industrial forest products, which are an important source of foreign exchange and rank fifth overall in non-oil exports. In a number of countries, notably Cameroon, Gabon, Ivory Coast, Malaysia, and the Philippines, current rates of timber harvesting and insufficient investment in management and reforestation will lead to a sharp decline in exports within 10-15 years. By the end of the century, the 33 developing countries that are now net exporters of forest products will be reduced to less than 10, and total developing country exports of industrial forest products are predicted to drop from their current level of more than $7 billion to less than $2 billion. This will have a significant impact on employment and income.

Small-scale artisinal activities. The extent of artisinal and other small-scale commercial enterprises based on forest products has received little study. However, it is becoming increasingly apparent that activities such as furniture-making, handicrafts, and charcoal production are a significant source of employment and income. In many countries, this represents one of the most important sources of employment after farming. The costs of deforestation in terms of its impact on these activities are vastly understated.

4. *Health impacts.*

Deforestation is affecting the health of rural and urban populations in developing countries through its impacts on nutrition and domestic water supply. Although impossible to quantify, deforestation affects the health sector in developed countries as well by reducing the stock of genetic resources of potential use in pharmaceutical development.

Nutrition. The effects of fuelwood scarcity and other impacts of deforestation on food production have already been noted. Fuelwood scarcity can have other important effects on nutrition. With the rising cost of fuelwood and charcoal in urban centers, and increasing scarcity in rural areas, many families are forced to alter eating patterns to an extent that impairs their health. Families may eat less nutritious quick-cooking foods. In other cases, the frequency of cooked meals has to be reduced, or food is inadequately cooked which reduces its digestibility and increases the threat of disease. Deforestation also affects food supplies through the loss of foods directly available from the forest. This is particularly significant in areas where forest wildlife accounts for a major portion of animal protein supplies.

Water supply. Deforestation affects the quantity and quality of domestic water supplies. This, in turn, impacts the health of large numbers of people, particularly in urban centers. The disturbance of water regimes from the loss of forest cover disrupts the steady supply of clean water, leading to shortages in the face of rising demand and the threat of disease. Water-borne diseases remain a major cause of infant mortality in the Third World.

5. *Biological impoverishment.*

Tropical moist forests harbor an estimated 50% of the world's plant and animal species. This wealth of biological diversity is a vast storehouse of genetic resources. Although less than one percent have been screened for their potential usefulness, tropical forest species have already made enormous contributions to agriculture, medicine, and in-

dustry. For example, wild genetic relatives of many modern food crops are found in the tropics. These wild relatives, and genes from other forest plants, can be used to genetically improve food crops as a means to increase productivity, to increase resistance to pests and diseases, or to increase their ability to withstand environmental stresses. In addition, tropical moist forests remain the world's primary source of raw materials for pharmaceutical development. Almost one out of five pharmaceutical products derives in one way or another from tropical moist forest plants and animals. Among the thousands of drugs fo tropical origin are some of the most significant cancer treatments yet developed.

Tropical species and populations are highly vulnerable to extinction through habitat destruction and other disturbances because of their limited and often patchy distribution. In addition to the outright extinction of species (or local populations of species), the fragmentation of tropical moist forest habitat into isolated patches can accelerate species loss (and the loss of genetic diversity) by disrupting the structure and dynamics of these complex ecosystems, setting in motion a gradual process of biological impoverishment.

Although difficult to quantify, the loss of biological diversity through deforestation has significant economic implications. Logic dictates that the 99 percent of tropical forest species that have yet to be studied will yield far greater benefits than the 1 percent that have already been utilized. Several wild and domesticated food plant varieties have become extinct and many more are seriously threatened. The continued loss of biological diversity will limit opportunities to broaden the genetic base for agriculture, medicine, and industry.

Open Access

Historically, forest lands in developing countries have been primarily a common-property resource. Resource management systems evolved that effectively regulated access to and exploitation of common-property forests, thereby preventing their depletion. For example, traditional methods of shifting cultivation within tropical forests, involving long fallow periods to allow forest recovery after cultivation and to restore productivity, are known to have been ecologically sound and sustainable systems. These traditional systems of common-property resource management have broken down under the combined pressures of internal and external social, economic, and political forces (4).

Rapid population growth has been an important factor in the breakdown of traditional resource management systems. Of equal importance in many areas, however, have been the effects of external political and commercial domination. The social organization of many traditional societies was weakened or destroyed during the colonial era. In addition, resources that were exploited primarily to meet subsistence needs became "monetized," leading to much more intensive rates of exploitation.

The destructive effects of colonialism have been exacerbated by national governments in many countries. Throughout the Third World, the ownership, control, and management of forests has shifted from local communities to national governments. Close to 80% of forest lands in developing countries are now state owned and under management of government agencies, primarily forestry departments (5). However, in most developing countries, these agencies are typically of recent origin and are relatively weak.

Planning and regulation of forest conservation and development programs is generally inadequate or ineffective.

With the breakdown of traditional resource management systems and the constraints to effective forest regulation by government agencies, forests are being exploited under open-access or virtually open-access conditions over much of their extent. Under open-access conditions, there is an absence of some form of property rights associated with resource use. This undermines individual incentives to reduce or regulate personal consumption of forest resources toward an optimal level of exploitation and to invest in their long term productivity, because the benefits of such action would only accrue to other resource users. Stated differently, each individual has an incentive to ignore the social costs of his resource use for fear that others will capture the benefits of the resource before he can. The absence of some form of regulated access to forests, combined with increasing resource demand associated with population growth and unequal access to agricultural land and other resources, results in a rate of aggregate use that exceeds the rate of forest renewal.

Inappropriate Policy Incentives

Government policies in many developing countries toward forest exploitation, and toward land use activities that lead to conversion of forests, have created virtual open-access situations and are a driving force behind deforestation. Governments are directly or indirectly subsidizing deforestation through economic policies—such as investment incentives, tax and revenue systems, credit programs, and government pricing—that lower the net costs or increase the private profitability of forestry and competing land use activities. These powerful economic incentives induce individual resource users to unduly favor short-term consumption over long-term management, leading to much higher rates of forest exploitation and conversion than would be the case without such policies (6).

Forest revenue systems, including the terms of forest concession agreements through which private timber operations gain access to public forests, can encourage rapid and wasteful exploitation in several ways. Commercial species in a virgin forest often have a high value because they are freely provided by nature. Whatever market value they have above the costs of harvesting, transport, and processing, is profit. In many countries with considerable forest resources, government forest revenue systems (royalties, taxes, fees) fail to adequately capture these profits, creating strong profit incentives that induce private investors to exploit all the profitable areas they can.

The nature of the charges levied on forest exploitation can also accelerate deforestation. Forest charges are often based on the volume of timber removed from a stand, rather than the volume of merchantable timber available, and do not differentiate between low and high-valued species. This provides an incentive to selectively remove only the high-valued species from a forest stand. This practice of "high-grading" not only depletes forests of high-valued species, but results in significant damage to the remaining trees in the stand since there is no incentive to minimize logging damage.

Another problem is the short time frame of many forest concession agreements, often less than the time required for a single forest rotation. This undermines incentives to sustainably manage

the forest since the contractor does not have a stake in its long-term productivity. This often results in careless logging practices, faster harvest schedules, and lack of investment in reforestation or other management activities. The fact that government forestry departments do not have the means to adequately monitor forestry operations and enforce the terms of concession agreements in remote forest areas only adds to these problems.

Similar forces are at work outside the forestry sector. Many governments have instituted policies that accelerate the conversion of forest lands to other land uses. For example, some countries have "you clear it, you own it" policies whereby farmers can gain property rights to forest land only by clearing it. This promotes expansion of shifting cultivation by small farmers. These farmers often gain ready access to forests by following on the heals of logging operations that have opened up forest areas.

Countries such as Brazil and Indonesia have undertaken very large-scale commercial agriculture and land settlement programs in forest areas that are supported by massive public subsidies. Multilateral and bilateral development assistance agencies have been major sources of funding for these programs. In the Indonesia transmigration program, the cost of resettling families to sparsely populated forest areas has risen to $10,000 per household. These subsidies increase the relative profitability of other land uses, providing strong economic incentives that accelerate the pace of deforestation. Brazil provides a dramatic example. Enormous public subsidies have led to rapid conversion of forest lands to pasture for large-scale cattle ranching operations. Conversion of forest to pasture accounted for 72 percent of the deforestation detected by Landsat monitoring up to 1980. Many of these cattle ranches have proven to be uneconomic (in addition to environmentally destructive) and after several yeras of operation usually fail, but forest conversion continues because most of the costs are assumed by the government through subsidies.

The divergence between private and social returns due to inappropriate policies toward forest exploitation and competing land uses can be very large. Private resource users reap excessive profits, often at great expense to society. The economic incentives that these policies create lead to lost public revenues, wastage of resources, and excessive public subsidies that do not yield significant public benefits. But the costs to society are even greater. The accelerated pace of forest depletion due to these policies results in externalities that impose significant additional costs.

III. The Need for Public Intervention

Externalities, open-access common property problems, and inappropriate policies lead to a divergence between private and social returns from forest exploitation. This provides strong incentives to over-exploit forests, resulting in depletion of the forest resource stock. The inability of the market to resolve this divergence means that some form of public intervention is needed to provide incentives to change the forest-depleting behavior of small and large-scale resource users. This is not meant to imply that only public sector solutions are feasible or desirable. It does mean that government leadership is essential to creating a policy and investment environment that will promote sustainable patterns of forest land use by both pub-

lic and private resource users. Similar efforts by the development assistance community are needed, which has a critical role to play in helping governments tackle these problems.

Although there is a growing awareness of the urgency of tropical deforestation, the response of most developing country governments and the international community falls far short of what is needed to address the problem. Forestry and agroforestry remain a relatively low investment priority. Most countries have forestry budgets that amount to less than two percent of their respective annual expenditures within the agriculture and energy sectors. The situation is largely the same within the development assistance agencies.

Why have governments and the development assistance community failed to respond? The reasons are many and varied, encompassing political, economic, social, and institutional factors. However, the inadequate response to date is due in no small part to a lack of political awareness of the role of forests in development and the economic and social consequences of forest depletion. Decision makers are rarely presented with an integrated overview of forestry issues and the consequences of forest mismanagement.

Efforts to address deforestation have focused largely on remedial measures through investment projects. These efforts must be greatly expanded. However, the project approach alone is inadequate because it does not address the fundamental causes of deforestation. Policies and incentive structures that influence forest land use and underlie forest depletion must simultaneously be addressed.

This requires changes in the conceptual framework and analytical approaches of development planning. The lingering view that issues of environmental protection are somehow "external" to the development process must be changed. Sustainable management of forest resources must be considered essential to achieving long-term development objectives, and should become an integral component of economic and social policy and macroeconomic planning. This requires a clear understanding of the economic costs of deforestation and the economic benefits of sustainable forest management. An expanded approach to economic analysis is needed that accounts for the true costs and benefits of forests and their use, and that can help guide efforts to initiate new policies and investment programs to address the underlying causes of deforestation.

An Expanded Approach to Economic Analysis

Economic analysis plays a central role in decisions that in large measure determine, and will continue to determin, the fate of tropical forests. All countries face the basic problem of how to allocate scarce resources to a variety of different uses in order to maximize the net benefit to society. Economic analysis can provide a convenient and consistent method for evaluating alternatives by assessing their costs and benefits and reducing them to a common measure for comparison.

However, the prevailing framework for economic analysis does not provide a sound basis for decisions related to forest resource use, and in fact is an important factor in their widespread misuse. Economic analysis as currently practiced fails to account for forest goods and services that do not have a market price, and generally ignores extra-market effects both now and in

the future. As a result, alternatives to mitigate these costs and the benefits of protecting and sustainably managing forests are undervalued.

The objective of an expanded approach to economic analysis is to provide decision-makers with as complete a picture as possible of the social costs and benefits of forests and their use. The analysis should provide information relevant to the needs of decision-makers and in a useable form. This requires practical methodologies for deriving operationally useful measures of the value of non-market goods and services.

Marginal opportunity cost as an analytic tool. A practical way to evaluate in economic terms the social costs of deforestation is to apply the concept of "marginal opportunity cost." The marginal opportunity cost of resource use is the cost to society of a marginal reduction in the stock of a given resource. Economic theory tells us that this cost should be equal to the price that individuals have to pay to utilize the resource. A price less than the marginal opportunity cost will stimulate overexploitation.

The marginal opportunity cost of resource use has three components—the marginal *direct* cost, the marginal *user* cost, and the marginal *external* cost. The direct cost is the cost to the user of harvesting the resource and is measured by the value of foregone output or leisure. The user cost component is the cost to future users of depleting the resource stock today. This can be evaluated in terms of the marginal cost of reestablishing the resource (for example, the marginal cost of reforestation) or of replacing the resource (for example, substituting kerosene for fuelwood). External costs are the costs imposed on others due to externality effects of resource use (as described in Section II above).

In deriving operationally useful measures of the "true" cost of forest resource use, the marginal external cost component is particularly significant. To estimate the marginal external cost of forest depletion, it is necessary to attach market values to non-market goods and services. This requires breaking down these goods and services into their physical characteristics, and relating changes of these characteristics (due to the physical effects of deforestation) to the production process of relevant commodities that are actually traded and have a value expressed as a market price.

To illustrate, consider the external effect of deforestation and reduced fuelwood supply on agricultural productivity. As described earlier, households respond to fuelwood scarcity by burning animal dung and crop residues that normally are used to help maintain soil productivity. The result is a decline in crop yields.

To calculate the marginal external cost from dung being used as a fuel instead of as a fertilizer would entail the following general steps:

(1) Determine fuel equivalent values for dung and wood;
(2) Determine fertilizer equivalent values for dung;
(3) Determine the incremental crop yield response for a unit input of dung (based on fertilizer response curves);
(4) Calculate lost agricultural output due to the marginal impact of fuelwood depletion on reduced fertilizer (dung) application.

The market value of this foregone output represents part of the marginal opportunity cost of deforestation.

Limits to Economic Analysis

To most effectively use economic analysis as an aid to decision-making, it is important to recognize its limitations. There are circumstances in which even an expanded approach to economic analysis can produce incomplete or misleading results.

Lack of biophysical data. To calculate the marginal opportunityu cost of forest depletion requires a thorough understanding of the complex physical linkages associated with deforestation. The need to integrate physical and biological considerations with economic analysis can present significant measurement problems. The biophysical data required for these calculations is often inadequate, particularly in developing countries that have not had the means for systematic collection of such data. Related to this is the paucity of knowledge of the workings of tropical ecosystems. Another complicating factor is the often location-specific nature of the impacts of deforestation, making generalizations difficult and the need for local data even greater.

As important as these constraints can be, they should not prevent attempts to account more fully for the social costs of deforestation. It is not necessary to quantify all physical relationships in the analysis. Often, the appraisal of just one or two extra-market effects is sufficient to give a significantly more accurate picture of benefits and costs. In addition, exact quantification is not required, nor are very technically sophisticated approaches. Of greater importance is the analytical process of taking into account as many relevant costs and benefits as possible. The use of sensitivity analysis to test assumptions can help overcome the uncertainty associated with limited data.

Irreversible effects and inter-generational equity issues. An important limitation to economic analysis is the treatment of inter-generational equity issues. Appraising the welfare effects of forest depletion on future generations poses major conceptual problems. Future benefits and costs must be expressed in present value terms. This requires the use of a discount rate, which is based on the opportunity cost of capital. Because the opportunity cost of capital is high, especially in developing countries, discount rates of 10 to 12 percent are commonly used in benefit-cost analyses. Discounting at this rate discourages investments with long-term benefits, while promoting projects with long-term costs. As a result, short-term economic interests are often favored at the expense of longer-term environmental concerns. Coping with inter-generational equity issues is most difficult where irreversible effects are involved. There is no clear understanding of how to appraise the costs of irreversible effects of deforestation, such as species extinction, or of how to evaluate the preferences of future generations. In such cases the marginal opportunity cost approach must be supplemented by other analytical methods and perspectives.

As a general rule, the greater the uncertainty about future preferences, the greater the weight that should be given to preserving future options. Although of limited use in clarifying future preferences, expanded economic analysis nevertheless can play an important role here. A more comprehensive accounting of the short-run benefits and costs of forests and their use should result in policies and investment decisions that to a greater extent will preserve options for future generations.

IV. Conclusion

Powerful economic factors are a driving force behind tropical deforestation. To address these factors requires changes in the prevailing approach to investment and policy decisions, which is based largely on conventional benefit-cost analysis. An expanded approach to economic analysis, based on the concept of marginal opportunity cost, will provide a more complete picture of the economic costs of tropical deforestation and the economic benefits of sustainable forest management. Although this approach involves conceptual and estimating problems, much more can be done using known techniques than is now being attempted.

The marginal opportunity cost of forest depletion has several important policy and investment implications. First, marginal opportunity cost can serve as an economic indicator of forest resource scarcity. That is, the higher the marginal opportunity cost of resource use, the more scarce a resource is relative to the demand for it. This can provide policy guidance to decision-makers and indicate priority areas for investment. Second, marginal opportunity cost can reveal the extent to which market prices do or do not reflect the social cost of forest resource use, and hence the extent to which markets approach or diverge from an optimal allocation of resources in terms of long-term sustainable use. Finally, the most far-reaching implications of an expanded approach to economic analysis will be in the realm of multi-sectoral policy and planning. Evaluating the physical linkages between forest resource use and agriculture, energy, and other sectors will demonstrate the need for more integrative, multi-sectoral approaches to policy-making and investment project planning. Only through a sustained commitment to forestry, agriculture, energy, and related rural development efforts can current trends in tropical deforestation be reversed.

Notes

1. In this paper, "tropical forests" refers to forests and trees in the humid and semi-arid/arid areas of developing countries. Thus, the term includes forest formations ranging from moist (or closed) tropical forests to dry (or open) woodlands.
2. There are important dimensions to the problem of tropical deforestation beyond purely utilitarian concerns, such as aesthetic and ethical issues associated with the destruction of natural habitats.
3. The review of the direct and indirect impacts of deforestation is based largely on "Tropical Forests: A Call for Action, Part 1," World Resources Institute, Washington, D.C., 1985.
4. R. Repetto and T. Holmes, "The Role of Population Growth in Resource Depletion," Population and Development Review, IX, December 1983, 609-632.
5. J. P. Lanly, "Tropical Forest Resources," FAO Forestry Paper No. 30, U.N. Food and Agriculture Organization, Rome, 1982.
6. This section is based on R. Repetto, "Creating Incentives for Sustainable Forest Development," World Resources Institute, Washington, D.C., (forthcoming).